



Zoos and public health: A partnership on the One Health frontier



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ABSTRACT

Today, accredited zoos are not just places for entertainment, they are actively involved in research for conservation and health. During recent decades in which the challenges for biodiversity conservation and public health have escalated, zoos have made significant changes to address these difficulties. Zoos increasingly have four key areas of focus: education, recreation, conservation, and research. These key areas are important in addressing an interrelated global conservation (i.e. habitat and wildlife loss) and public health crisis. Zoo and public health professionals working together within a One Health framework represent a powerful alliance to address current and future conservation and public health problems around the world. For researchers, practitioners, and students, the collaboration between zoos and public health institutions offers the opportunity to both teach and operationalize this transdisciplinary approach. Using examples from our programs, we give a template for moving forward with collaborative initiatives and sustainable solutions involving partners in both zoos and public health institutions. We provide examples of cooperative programs and suggest a model for consideration in the development of further activities in this area.

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The increasingly international work of both public health institutions (such as governments, non-governmental organizations, non-profit organizations, and/or schools of public health and medicine) and accredited zoos, including over 200 zoological facilities in North America accredited by the Association of Zoos and Aquariums (AZA) and 300 member facilities in the European Association of Zoos and Aquaria, reflects the reality that our world is shrinking [1]. An alliance between public health educators, institutions, and zoos—to explore connections between human, animal and ecological health and to craft innovative solutions—represents a new frontier in the field of One Health, defined as the collaboration across disciplines to improve the health of humans, animals, and the environment [2].

An estimated 700 million people visit the world's accredited zoos each year [3]. Visitors ranging in age from days old to centenarians come to zoos to have fun and learn about wild animals and wild places. What they might not know is that in recent decades accredited zoos and aquariums have expanded beyond education and recreation, and are now fully committed to conservation and research [4,5]. Worldwide, accredited zoos and aquariums spend roughly \$350 million dollars on

in situ conservation projects [3]. The research zoos conduct to conserve biodiversity often coincides with the areas of emerging diseases at the interface between human and animal health [2].

Emerging Infectious Diseases (EID) are increasingly recognized as a serious threat to both human health and biodiversity [6,7]. It is estimated that 75% of EID are zoonotic and, of these, 70% originate in wildlife populations [8]. Examples of EID include Ebola virus, Hantavirus, avian influenza, and Marburg virus. These and the hundreds of other emerging diseases in human and non-human animal populations have led to catastrophic effects on both human and animal health. As the human population grows close to 8 billion and continues to encroach into once pristine wildernesses, the result is often an increase in human-wildlife interactions which is an important factor in zoonotic disease transmission [7,9]. Understanding and controlling EID in the age of expanded travel and trade requires a One Health framework [10]. For researchers, practitioners, and students, the collaboration between zoos and public health institutions offers the opportunity to both teach and operationalize this transdisciplinary approach.

One example of work at the domestic animal/wildlife/human interface is the dromedary camel project in Laikipia County, Kenya, led by the Saint Louis Zoo Institute for Conservation Medicine since 2012. This collaboration involves the Zoo and a number of in-country partners as well as the Master of Public Health Program at the University of Missouri-Columbia. The focus of this project is to gain a better understanding of the epidemiology of zoonotic pathogens (e.g., Q fever (*Coxiella burnetii*) and *Brucella* spp.) in dromedary camels in Kenya [11]. Following the

Abbreviations: EID, Emerging Infectious Diseases; MERS, Middle East Respiratory Syndrome; GDP, Gross Domestic Product; ADHD, Attention Deficit Hyperactivity Disorder; MPH, Master of Public Health; MSc, Master of Science.

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emergence of Middle East Respiratory Syndrome (MERS), retrospective samples banked from our project offered an important source of data on this significant and emerging zoonotic disease [12]. Additionally, through this project we have trained a number of Kenyan and American veterinary, MSc and public health students to better understand the disease risks associated with changing environmental conditions, protein sources for humans, and the inevitable increase in interactions at the domestic animal/wildlife/human interface. This project is just one example of a key transdisciplinary One Health program in which zoos and public health institutions are integrated to study EID at this interface.

Many zoos and aquariums are involved in conservation across the globe, working to preserve biodiversity and in many cases studying diseases of conservation concern. A map of conservation projects initiated by accredited zoos and aquariums is shown in Fig. 1 [2]. These projects integrate various disciplines within the realm of natural and social sciences, with the goal to preserve the world's biodiversity. Within this figure, there are areas where zoo-based *in situ* work overlays disease emergence and biodiversity hotspots, further exhibiting the important role zoos and aquariums have in regards to One Health. Although some of the disease emergence hotspots, as indicated on the map, do not have *in situ* projects marked, most of these areas are found in cities where accredited zoos and aquariums exist and these institutions may serve a similar role to *in situ* projects in more remote regions of the world.

Zoos and aquariums conduct disease surveillance programs that span the globe from fence to field [2,13]. Zoological health professionals study the epidemiology, pathology, and clinical implications of infectious diseases that play an important role in the long-term survival of species and often also have direct human health consequences (*e.g.*, zoonotic diseases and diseases associated with degraded environments). These include, among many others, Ebola virus in human and non-human primates, rabies and canine distemper in carnivores, fibropapillomatosis in sea turtles, and chytridiomycosis in amphibians

[14]. Further, the animals housed at accredited zoos may serve as sentinels of disease for humans, wildlife, and domestic animals [2]. For example, based on the bird species that did or did not experience morbidity and/or mortality at the Bronx Zoo in New York, public health officials were made aware of the presence of West Nile Virus (WNV) in the western hemisphere by veterinary staff at the Zoo [15]. In fact, the public health concerns associated with the arrival of WNV in the USA led to the launch of the National Surveillance of West Nile Virus in Zoological Institutions, which later became the AZA Avian Influenza Network [16]. These programs were the start of a partnership between zoos and public health agencies to utilize zoo collection animals as part of a nationwide disease surveillance system [17].

Along with EID, debilitating chronic non-infectious diseases such as heart disease, cancer, diabetes, and obesity represent another worldwide public health crisis [18]. Chronic non-infectious diseases globally cost US\$30 trillion dollars, 48% of global Gross Domestic Product (GDP) in 2010 [19]. Also, losses attributed to mental illness will account for an additional US\$16.1 trillion loss over the next 20 years [19]. By 2020, it is estimated that 7 out of 10 deaths in developed countries will be due to non-infectious diseases [18]. Accredited zoos have the potential to offer direct health benefits to visitors which may help to lower risk factors associated with chronic disease. For example, recent studies explore the direct benefits zoos offer for human health. In one study, a single zoo visit was shown to decrease blood pressure and result in approximately 6000 steps walked per visit [20]. In another study, visitors interacting with stingrays in a touch tank at a zoo felt happier, more energized, and less tense after their visit [21]. The impact that zoo visits have on human health and well-being are still poorly understood, but warrant further study. Engagement with the outdoors provides humans with psychological, emotional, spiritual and even physical benefits and it is thus imperative that we also understand how zoos impact human health [20–27].

Globally, as people continue to migrate into cities, less time is spent outdoors. The average American child, for example, spends less than

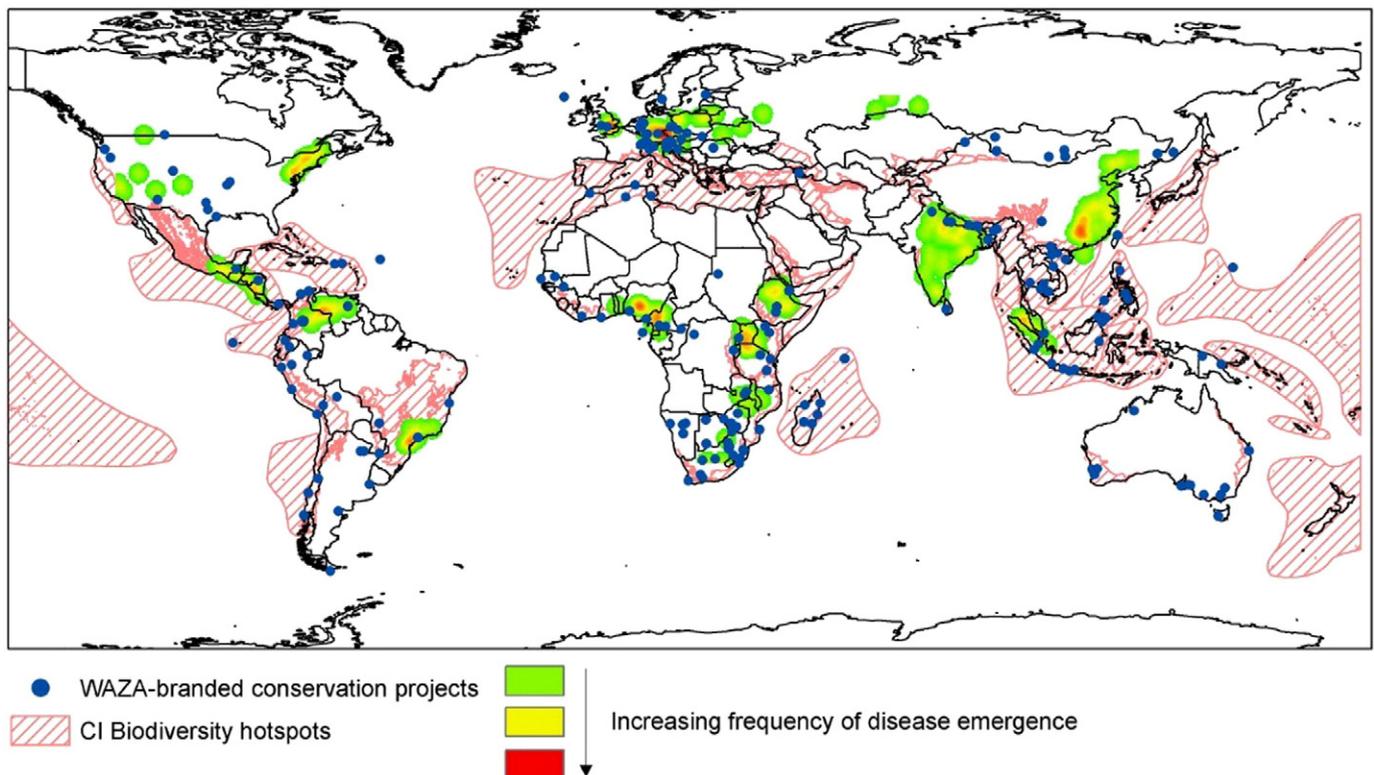


Fig. 1. The global footprint of *in situ* programs branded by the World Association of Zoos and Aquariums, which are found in many of the Earth's biodiversity and emerging disease hotspots. (Map modified from data presented in Jones et al., [8]).

30 min per day of unstructured time outside [28]. This is problematic because exposure to nature has health benefits, including a positive effect on mental processes, behavior, cognitive ability and function; physical function and health; reduction of incidence of infectious disease; positive effects for individual, community, cultural, and spiritual well-being [27]. Also, being outside can help vision by lowering the chance of nearsightedness and improving distance vision [26], can reduce stress levels in children [24], aid in emotional development [29], foster an improvement in critical thinking skills [30], and result in a reduction in Attention Deficit Hyperactivity Disorder (ADHD) symptoms [31]. In a densely populated urban environment, zoos provide opportunities for people of all ages to be exposed to greater biodiversity and the outdoors.

Finally, knowledge of the role of zoos in comparative medical research is growing [2,32]. Studies of zoo animals may unlock diseases of concern for domestic animals, wildlife and humans. This across taxa approach to a number of human and veterinary health concerns (e.g. cancers, arthritis) has been explored with zoo collection animals [2].

Beyond the contributions to health, well-being and research described above, the partnership between zoo and public health professionals has the capacity to provide transdisciplinary training opportunities in both conservation and public health for tomorrow's professionals. The partnership between the Saint Louis Zoo Institute for Conservation Medicine and the University of Missouri – Columbia Master of Public Health program provides one useful model for how this can be done. Together, in the first four years, we have created opportunities for 7 Master of Public Health (MPH) students to gain real-world experience alongside Zoo staff. The MPH field placement students have researched the impacts of endocrine disruptor chemicals on human and wildlife health, and EID among camels in Kenya, as two examples. A number of these students have contributed to the growing body of One Health literature by publishing their work [12,33,34]. Through these projects, public health students have gained a better understanding of the conservation challenges that threaten human health and, more importantly, the actions that may be taken to help both human public health and wildlife and wild land conservation. Partnerships such as this can provide students the knowledge and tools to address the public health challenges of the 21st century in a transdisciplinary One Health approach.

Charles Darwin is reported to have said that the species which survive are not necessarily the strongest or the most intelligent, rather they are the ones which are the most adaptable to change [35]. We are living in a century of unprecedented global change. As we enter the Anthropocene—the age of human domination—it is only through a change in our approach to public health that we will be able to effectively meet the challenges that threaten human health and global stability [2,36].

Recommendations

There is a great and vastly untapped partnership potential between accredited zoos and aquariums and public health institutions. We are asking public health officials to foster this potential by partnering with their local zoos to help fight public health problems through education, conservation, recreation and research. For example, graduate and undergraduate public health programs should, like the Saint Louis Zoo and the University of Missouri – Columbia, develop collaborative training programs where students can learn, and research can be performed to further understand the health of humans, animals and the environment. Through education, conservation, recreation and research a partnership between public health and zoo personnel represents a fresh approach, and it is one adaptation that may provide the solutions necessary to address the changing public health and conservation challenges of our time.

Conflict of interest statement

The authors have no conflict of interest to declare.

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